INFLUENCE OF TEMPERATURE ON GASEOUS LOSS OF NITROGEN FROM SOME SOILS OF TAIWAN UNDER FLOODED CONDITIONS

by

T. T. YEN

In has been found in previous experiment[12] that nitrogen may lose in gaseous form from some soils of Taiwan under flooded conditions even though nitrogen has been applied in ammonium form. The loss is probably a result of successive processes of nitrification and denitrification which may take place in upper oxidative and lower reductive layers of flooded soil respectively, as pointed out by Shioiri[8]. Since both processes are microbiological, it is obvious that they may be influenced by temperature. To investigate the influence of temperature on gaseous loss of nitrogen in flooded soil supplied with ammonium-nitrogen, experiment has been carried out.

SOIL AND METHOD

Soils of Taipei silt loam, Yilan silty clay loam, Pinchen loam, Yuanlin clay loam, Hsinying clay loam and Pintung silty clay loam are used for experiment. Their pH-values and contents of organic carbon and total nitrogen are shown in Table 1.

Table 1. Properties of soils

Soil type	Yilan si.c.l.	Taipei si.l.	Pinchen l.	Yuanlin c.l.	Hsinying c.l.	Pintung si.c.l.
Symbol	Yilan	Taipei	Pinchen	Yuanlin	Hsinying	Pintung
pH-value	6.2	5.6	4.6	6.8	6.8	7.0
Org.-C, %	1.33	1.39	1.02	1.82	0.70	1.09
Total-N, %	0.186	0.177	0.121	0.255	0.092	0.154

Method of estimating amount of gaseous loss of nitrogen.

Fifteen-gram portions of air dried soils are taken in 50 ml beakers, supplied with 5 mg ammonium-nitrogen in form of ammonium sulfate and flooded with water. Liming to a neutral pH-value is carried out, if necessary, by adding saturated solution of calcium hydroxide 10 days before applying ammonium sulfate. The soils are incubated at 10°, 20° and 30°C. for 2 months, or allowed to stand at a dark corner of a sunny room during the months of the 1st and the 2nd crop seasons of paddy rice and during winter months. The 1st crop season is from March 18 to July 15, 1960, the 2nd crop season from July 10 to November 6, 1959, and winter months from January 8 to March 7, 1960. Room temperaure is recorded

by a temperature recorder through experimental periods. The mean of room temperatures at 10:00 A. M., 2:00 P. M. and 9:00 P. M. of every day is taken as a daily avarage temperature. Fluctuation of avarage temperatures of 5-day periods is presented in Figure 1. Water is supplemented occasionally to keep flooded conditions. Each treatment is replicated 8 times. The soils are analyzed for total nitrogen at 1-month intervals. In order to include nitrite- and nitrate-nitrogen in Kjeldahl analysis, the soils are treated with potassium permanganate solution and dilute sulfuric acid, and then with reduced iron before digesting with sulfuric acid. Difference is obtained between the contents of total nitrogen before and after incubation, and regarded as the amount of gaseous loss of nitrogen.

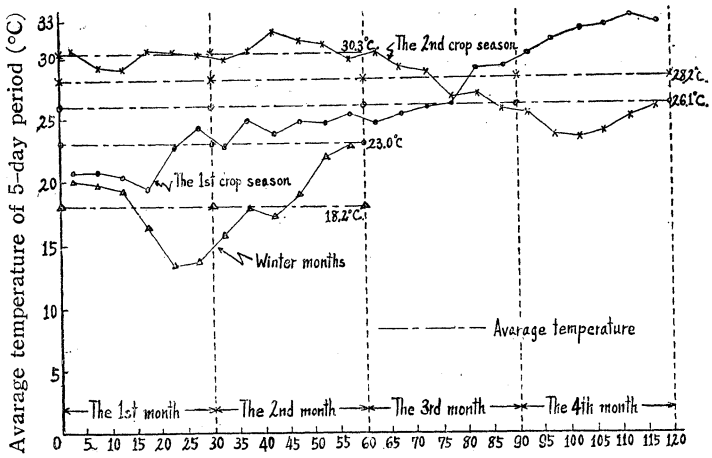

Figure 1. Avarage temperatures of 5-day periods through experimental periods.

Method of investigating changes in contents of ammonium- and nitrate-nitrogen in flooded soil.

Thirty-gram portions of air dried soils are taken in 300 ml beakers, supplied with 20 mg ammonium-nitrogen in form of ammonium sulfate and flooded with water. If necessary, lime is appled as above. The soils are incubated at 10°, 20° and 30°C. for 9 weeks and analyzed for ammonium- and nitrate-nitrogen at 1-week intervals by the method described by Piper.[9]

RESULT

(1) Gaseous loss of nitrogen in flooded soil supplied with ammonium-nitrogen and incubated at 10°, 20° and 30°C.

Tables 2a, 2b, 2c, 2d, 2e and 2f show the amounts of gaseous loss of nitrogen in flooded soils supplied with ammonium-nitrogen and incubated at 10°, 20° and 30°C. and the results of statistical analyses.

It may be found that the loss of nitrogen is very significantly influenced by temperature, soil type and incubation period. In temperature range of 10°-30°C., high temperature is favorable for the loss. The amount of nitrogen loss is large in

Yilan silty clay loam, Yuanlin clay loam and Pintung silty clay loam having high pH-values and high contents of total nitrogen and organic matter. In Pinchen loam which is a strongly acidic soil the loss of nitrogen is least. Liming acidic soil to a neutral pH-value increases the loss remarkably. These results suggest the

Table 2a. Gaseous loss of nitrogen in flooded soil, supplied with ammonium-nitrogen (0.333 g/kg soil) and incubated at 10°, 20° and 30°C. Means of 8 replications (N g/kg soil)

Soil type(a)		Taipei		Taipei+L		Pinchen		Pinchen+L		Yilan		Yuanlin		Mean
Incub. period (months)		1	2	1	2	1	2	1	2	1	2	1	2	
Incub. temp. °C	10	0.075	0.086	0.289	0.366	0.003	0.035	0.160	0.255	0.098	0.135	0.228	0.260	0.163
	20	0.150	0.245	0.340	0.433	0.010	0.028	0.199	0.239	0.245	0.290	0.258	0.326	0.230
	30	0.244	0.353	0.479	0.469	0.013	0.034	0.284	0.351	0.280	0.364	0.326	0.399	0.298
Mean		0.156	0.228	0.369	0.423	0.008	0.032	0.214	0.282	0.208	0.263	0.271	0.328	

L.S.D. $\begin{cases}0.05\\0.01\end{cases}$ For soil type: $\begin{matrix}0.015\\0.019\end{matrix}$ For temperature: $\begin{matrix}0.010\\0.014\end{matrix}$ For incub. period: $\begin{matrix}0.008\\0.011\end{matrix}$

Note: (*a*) cf. Table 1. +L indicates that soil is limed to pH 7.

Table 2b. Gaseous loss of nitrogen ie flooded soil, supplied with ammonium-nitrogen (0.333 g/kg soil) and incubated at 10°, 20° and 30°C. Means of 8 replications (N g/kg soil)

Soil type(a)		Hsinying		Pintung		Mean	L.S.D. $\begin{cases}0.05\\0.01\end{cases}$
Incub. Period (months)		1	2	1	2		
Incub. temp. °C	10	0.059	0.086	0.109	0.114	0.092	For temp: $\begin{matrix}0.014\\0.018\end{matrix}$
	20	0.089	0.144	0.215	0.265	0.172	
	30	0.150	0.196	0.303	0.365	0.253	For Incub. period and soil type: $\begin{matrix}0.011\\0.015\end{matrix}$
Mean		0.099	0.142	0.209	0.248		

Note: (*a*) cf. Table 1.

Table 2c. Analysis of variance

Soil type	Soil types in Tab. 2a.		Soil types in Tab. 2b.	
Source of variation	Degree of freedom	F-value	Degree of freedom	F-value
Block	7	1,429	7	—
Soil type	5	575,762**	1	374,769**
Temperature	2	337,104**	2	281,548**
Incubation period	1	153,124**	1	54,385**
Soil type×temp.	10	20,929**	2	42,067**
Soil type×incub. period	5	2,047	1	—
Temp.×incub. period	2	1,500	2	4,981**
Soil type×temp.×incub. period	10	3,894**	2	—
Error	252		77	

Note; ** Significant at 0.01 level.

Table 2d. Interaction between soil type and temperature

Soil type[a] / Temp.	Taipei	Taipei +L	Pinchen	Pinchen +L	Yilan	Yuanlin	Hsinying	Pintung
10°C	−0.042**	−0.001	0.066**	0.017**	−0.052**	0.012	0.034**	−0.034**
20°C	0.008	−0.009	−0.001	−0.024**	0.033**	−0.007	−0.008	0.008
30°C	0.034**	0.010	−0.065**	0.007	0.019**	−0.005	−0.026**	0.026**
L.S.D. 0.05	0.013						0.008	
L.S.D. 0.01	0.017						0.010	

Note: (*a*) cf. Tables 1 and 2a. ** Significant at 0.01 level.

Table 2e. Interaction between temperature and incubation period (Hsinying clay loam and Pintung silty clay loam)

Incub. period / Temp.		10°C	20°C	30°C
Months	1	0.0124**	−0.0057	−0.0067
	2	−0.0124**	0.0057	0.0067
L.S.D. 0.05		0.0078		
L.S.D. 0.01		0.0104		

Note: ** Significant at 0.01 level.

Table 2f. Interaction between soil type, temperature and incubation period

Soil type[a]		Taipei		Taipei +L		Pinchen		Pinchen +L		Yilan		Yuanlin	
Incub. period (months)		1	2	1	2	1	2	1	2	1	2	1	2
Temp. °C	10	0.023**	−0.023**	−0.017**	0.017**	−0.009	0.009	−0.009	0.009	0.004	−0.004	0.008	−0.008
	20	−0.010	0.010	−0.016**	0.016**	0.006	−0.006	0.012	−0.012	0.009	−0.009	−0.002	0.002
	30	−0.013*	−0.013*	0.033**	−0.033**	0.003	−0.003	−0.004	0.004	−0.013*	0.013*	−0.006	0.006
L.S.D. 0.05		0.013											
L.S.D. 0.01		0.017											

Note: (*a*) cf. Tables 1 and 2a. *** Significant at $\begin{matrix}0.05\\0.01\end{matrix}$ level.

importance of pH-value of soil for the gaseous loss of nitrogen. Although Hsinying clay loam is a neutral soil, the amount of nitrogen loss is less than in other neutral soils. Tables 2a and 2b show that a large part (60–90%) of nitrogen lost in 2 months' incubation period disappears from soil in the 1st month, excepting in Pinchen loam.

The percentages of nitrogen loss at various temperatures to total nitrogen including applied nitrogen are shown in Table 3. It reveals that excepting for Pinchen loam in which the percentage is very low the soils lose 4–10% of total nitrogen in 2 months at 10°C., 11–16% at 20°C. and 16–20% at 30°C. Liming acidic soil increases the percentage remarkably.

Table 3. Percentage of nitrogen loss to total nitrogen including added ammonium-nitrogen (Incubation period: 2 months)

Soil type(a)		Taipei	Taipei +L	Yilan	Pinchen	Pinchen +L	Hsinying	Yuanlin	Pintung
Total-N+NH_4-N (g)		2.10	2.05	2.19	1.54	1.56	1.25	2.58	1.87
Incub. temp. °C	10	4.1	17.8	6.1	2.3	16.3	6.9	10.1	6.1
	20	11.7	21.1	13.2	1.8	15.3	11.5	12.6	14.2
	30	16.8	22.9	16.6	2.3	22.5	15.7	15.5	19.5

Note: (*a*) cf. Tables 1 and 2a.

(2) Gaseous loss of nitrogen in flooded soil allowed to stand at room temperature in months of the 1st and the 2nd crop seasons and in winter months.

The amounts of nitrogen lost from soils in months of the 1st and the 2nd crop seasons of paddy rice are presented in Tables 4a, 4b and 4c together with the results of statistical analyses. The same data for winter months are given in Tables 5a, 5b and 5c.

Table 4a. Gaseous loss of nitrogen in flooded soil in the 1st and the 2nd crop seasons of paddy rice. Means of 8 replications (N g/kg soil)

Soil type(a)		Taipei		Taipei +L		Yilan		Mean	Hs	Yu	Pi	Mean	Hs	Yu	Pi	Mean
Crop season		1st	2nd	1st	2nd	1st	2nd		1st				2nd			
Incub. period (months)	1	0.120	0.116	0.304	0.260	0.263	0.316	0.230	0.103	0.265	0.203	0.190	0.144	0.233	0.251	0.209
	2	0.244	0.158	0.493	0.390	0.364	0.378	0.338	0.201	0.405	0.309	0.305	0.231	0.308	0.263	0.267
	3	0.365	0.255	0.556	0.500	0.448	0.338	0.425	0.201	0.438	0.380	0.340	0.291	0.359	0.328	0.326
	4	0.405	0.334	0.589	0.501	0.479	0.459	0.459	0.235	0.429	0.384	0.350	0.281	0.355	0.300	0.312
M-value		Insignificant							Insignificant				Insignificant			
L.S.D. $\begin{cases}0.05\\0.01\end{cases}$		For soil type: 0.098 For incub. period: $\begin{matrix}0.091\\0.150\end{matrix}$							For soil type: $\begin{matrix}0.019\\0.025\end{matrix}$ For incub. period: $\begin{matrix}0.022\\0.029\end{matrix}$				For soil type: $\begin{matrix}0.013\\0.017\end{matrix}$ For incub. period: $\begin{matrix}0.015\\0.020\end{matrix}$			

Note: (*a*) Hs, Yu and Pi indicate Hsinying, Yuanlin and Pintung respectively. (cf. Tables 1 and 2a.)

v-value between crop seasons: Insignificant

Table 4b. Analysis of variance

Soil type(a)	Taipei, Taipei+L, Yilan				Hs, Yu, Pi The 1st season		Hs, Yu, Pi The 2nd season	
Source of variation	Degree of free.	F′-value	n_1	n_2	Degree of free.	F-value	Degree of free.	F-value
Soil type	2	16,978**	2	4	2	230,266**	2	73,059**
Crop season	1	2,659	1	3				
Incub. period	3	19,739**	3	4	3	89,682**	3	101,111**
Soil type×crop season	2	9,417*	2	6				
Soil type×incub. period	6	4,682*	6	6	6	2,574*	6	5,606**
Crop season×incub. period	3	4,357*	3	6				
Soil ty.×cr. season×incub. p.	6	1,807	6	126				
Error	126				84		84	

Note; (*a*) cf. Table 4a. * ** Significant at $\begin{matrix}0.05\\0.01\end{matrix}$ level.

Table 4c. Interactions between soil type and incubation period, and between soil type and crop season

Soil type(a)		Taipei	Taipei +L	Yilan	The 1st crop season			The 2nd crop season		
					Hsinying	Yuanlin	Pintung	Hsinying	Yuaulin	Pintung
Incub. period (months)	1	0.002	−0.035**	0.034*	0.023*	−0.013	−0.010	−0.024**	−0.012	0.035**
	2	−0.024*	0.017	0.007	0.007	0.012	−0.019*	0.006	0.006	−0.011
	3	−0.002	0.016	−0.015	−0.027*	0.010	0.018	0.007	−0.002	−0.005
	4	0.024*	0.002	−0.026*	−0.003	−0.009	0.012	0.011	0.008	−0.019**
L.S.D.	0.05	0.023			0.019			0.013		
	0.01	0.035			0.025			0.017		
Crop Season	1st	0.011	0.013	−0.024**						
	2nd	−0.011	−0.013	0.024**						
L.S.D.	0.05	0.014								
	0.01	0.020								

Note: (a) cf. Tables 1 and 2a.

* ** Significant at 0.05 / 0.01 level.

Table 5a. Gaseous loss of nitrogen in flooded soil in winter months. Means of 8 replications (N g/kg soil)

Soil type(a)		Taipei	Taipei +L	Yilan	Yilan +L	Pinchen +L	Hsinying	Yuanlin	Pintung	Mean
Incub. period (months)	1	0.064	0.276	0.178	0.299	0.153	0.095	0.189	0.158	0.176
	2	0.146	0.400	0.196	0.435	0.226	0.159	0.301	0.185	0.256
L.S.D.	0.05	Forsoil type: 0.029			For incub. period: 0.014					
	0.01	Forsoil type: 0.038			For incub. period: 0.019					

Note: (a) cf. Tables 1 and 2a.

Table 5b. Analysis of variance

Source of variation	Degree of freedom	F-value
Soil type	7	84,071**
Incub. period	1	120,354**
Soil type×Incub. period	7	4,366**
Error	112	

Note: ** Significant at 0.01 level.

Table 5c. Interaction between soil type and incubation period

Soil type(a) / Incub. period		Taipei	Taipei +L	Yilan	Yilan +L	Pinchen +L	Hsinying	Yuanlin	Pintung
Months	1	−0.001	−0.022**	0.031**	−0.028**	0.003	0.008**	−0.016**	0.026**
	2	0.001	0.022**	−0.031**	0.028**	−0.003	−0.008**	0.016**	−0,026**
L.S.D.	0.05	0.006							
	0.01	0.008							

Note: (a) cf. Tables 1 and 2a. ** Significant at 0.01 level.

Again it is indicated in the tables that a large part of nitrogen lost in the whole flooding period disappears in the early period. The difference between the amounts of nitrogen loss in both crop seasons is not significant. But from Table 6, in which the losses in the 1st crop season and in winter months are compared, it may be found that the soils lose less nitrogen in winter months than in the 1st crop season.

Table 6. Result of v-test for significance of difference between gaseous loss of nitrogen in the 1st crop season and winter months

Soil type(a)	Gaseous loss of nitrogen after flooding for 2 months. (N g/kg soil)		V-value	
	The 1st season	Winter months		
Taipei	0.244	0.146	3.161**	
Taipei+L	0.493	0.400	1.764*	t (α 0.10; 0.02)
Yilan	0.364	0.196	7.468**	=1.645; 2.326
Yuanlin	0.405	0.301	3.325**	
Pintung	0.309	0.185	3.416**	

Note: (a) cf. Tables 1 and 2a. $\overset{*}{**}$ Significant at $\overset{0.05}{0.01}$ level.

(3) Changes in contents of ammonium- and nitrate-nitrogen in flooded soil.

Figures 2a, 2b and 2c show the changes in contents of ammonium-nitrogen in flooded soils which have received the application of ammonium-nitrogen at the rate of 20 mg nitrogen to 30 g soil and have been incubated at 10°, 20° and 30°C.

They indicate that decrease in content of ammonium-nitrogen is slower in Taipei silt loam and Yilan silty clay loam than in other soils having high pH-values. In Taipei silt loam incubated at 10° and 20°C. the content of ammonium-nitrogen keeps a practically constant high level, but it decreases when lime is applied. In any soil the rate of decrease of ammonium-nitrogen is about the same at 10° and 20°C. and it is rapid at 30°C.

The determination of nitrate-nitrogen, the data of which have not been presented here indicates that its content is usually less than 1 mg in 30 g soil treated as above. But in Yilan silan clay loam and Pintung silty clay loam some nitrate-nitrogen can accumulate after flooding for 6 or 7 weeks. The content is less than 5 mg in 30 g soil, equivalent to 166 p. p. m.

DISCUSSION

It is a well established fact that nitrogen loses in gaseous form from flooded soil. As the causes of the loss the followings are possible:

(1) loss as free ammonia,

(2) loss as nitrogen gas evolved by reactions between nitrous acid and ammonium ion or amino acids,

(3) loss as gaseous nitrogen oxides formed by decomposition of nitrites under acidic conditions, and

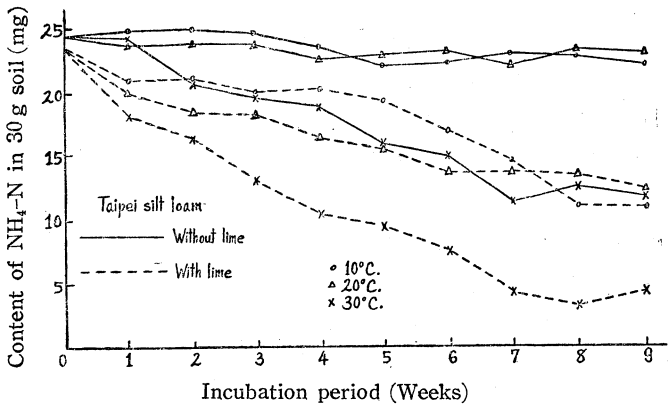

Figure 2a. Change in content of NH_4-N in flooded soil, supplied with 20 mg NH_4-N per 30 g soil and incubated at 10°, 20° and 30°C. (Taipei silt loam, with and without lime).

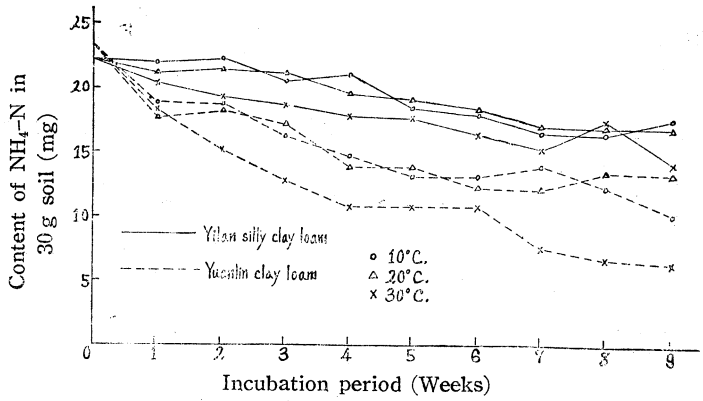

Figure 2b. Change in content of NH_4-N in flooded soil, supplied with 20 mg NH_4-N per 30 g soil and incubated at 10°, 20° and 30°C. (Yilan silty clay loam and Yuanlin clay loam).

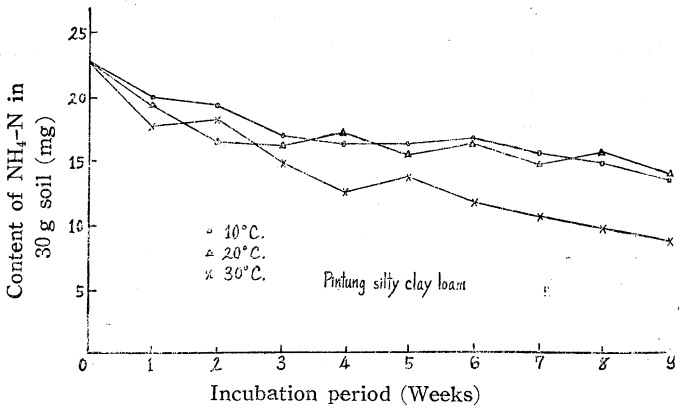

Figure 2c. Change in content of NH_4-N in flooded soil, supplied with 20 mg NH_4-N per 30 g soil and incubated at 10°, 20° and 30°C. (Pintung silty clay loam).

(4) loss as nitrogen gas and nitrogen oxides as a result of denitrification.

The loss of nitrogen as free ammonia will not be significant in soil excepting in that having high pH-value and having received the application of large amount of organic nitrogen or free ammonia. In previous investigation of the author[12] it has been found that nitrogen loss due to this cause is neglegible under about the same conditions as in present experiment. For the 2nd and the 3rd causes being important large amount of nitrites must present in soil having pH-values lower than 5. It does not seem practical that such conditions prevail in soils used in the above experiment. It is generally accepted that nitrogen loss through chemical reactions is not important in usual soil[2]. Although it is impossible to decidedly conclude which cause is most important from the above results, it is very probable that denitrification is the principal cause of nitrogen loss reported above.

The process of denitrification in soil supplied with ammonium-nitrogen is possible only when the nitrogen has been nitrified. As both processes of nitrification and denitrification are microbiological, they are obviously influenced by temperature and pH-value of soil. It has been known that neutral pH-values of soil are favorable for both processes and that optimum temperature for nitrification lies between 30° and 35°C. and that for denitrification is 25°C. or higher.[1,4,6,7,11] The experiments presented above confirm the results of earlier investigators. The amount of gaseous loss of nitrogen is larger in neutral soils than in acidic soils. And liming acidic soil to a neutral pH-value increases the loss very significantly. Although Hsinying clay loam is a neutral soil, the amount of the loss is less than in other neutral soils. This may be ascribed to its low contents of total nitrogen and organic matter. Low content of organic matter will make the soil less reductive. As shown by Shibuya et al.[10] and Chou[5] who investigated Eh-values of flooded soils of Taiwan, the depresseion of Eh-value of soil after flooding is less remarkable in Hsinying clay loam than in other soils. So some nitrate-nitrogen can accumulate in it when ammonium-nitrogen is applied and the soil is flooded for 4 weeks, as found by the author.[12]

Because of facts that loss of nitrogen as free ammonia is not significant in usual soil and that immobilization of ammonium-nitrogen does not cause decrease in total nitrogen, the process of nitrification must be responsible for the decrease in content of ammonium-nitrogen shown in Figures 2a, 2b and 2c. Denitrification may follow nitrification in flooded soil, so nitrate-nitrogen cannot accumulate in large amount excepting in Yilan silty clay loam and Pintung silty clay loam flooded for 6 or 7 weeks. The accumulation of nitrate-nitrogen in the soils may be due to the fact that easily decomposable organic matter decreases as a result of flooding and conditions become less reductive. The results of earlier investioators[3,5,10]show that rapid depression of Eh-value takes place in the 1st week of flooding period and the minimum value is attained after flooding for several weeks, after which the value is practically constant or increases slightly.

The fact that content of ammonium-nitrogen keeps a practically constant and

high level in Taipei silt loam has also been found in previous investigation.[12] This fact must be common to acidic soils, because Pinchen loam behaves quite similarly in this respect[13] and it is well known that ammonification can proceed but nitrification is slow in acidic soil.

From the facts that a large part of nitrogen lost during a flooding period disappears in early period and that remarkable decrease in content of ammonium-nitrogen takes place in the 1st week of a flooding period in soils having high pH-values, it is probable that nitrification can proceed actively in soil, presumably in surface layer, immediately after flooding, if conditions are favorable.

Paddy rice is grown two seasons in a year in most part of Taiwan, each season being about 4 months. The 1st crop season is from February to July, the 2nd season is from July to November, varying from location to location. Since fluctuation of temperatures in both seasons is not quite the same as shown in Figure 1, it is logical to assume that nitrogen loss in both seasons may be different. But this assumption cannot be confirmed in the above experiment. It has, however, been shown that the amount of nitrogen loss is smaller in winter months than in both crop seasons.

SUMMARY

Experiments have been carried out in order to investigate the influences of temperature on gaseous loss of nitrogen and on changes in contents of ammonium- and nitrate-nitrogen in some soils of Taiwan under flooded conditions. The soils used in the experiments are Taipei silt loam, Yilan silty clay loam, Pinchen loam, Yuanlin clay loam, Hsinying clay loam and Pintung silty clay loam. The soils are incubated at various temperatures under flooding conditions after adding ammonium-nitrogen, and analyzed for nitrogen of various forms. The decrease of total nitrogen is regarded as the amount of gaseous loss of nitrogen. The following results are obtained:

(1) In temperature range of 10°–30°C., gaseous loss of nitrogen, probably due to successive processes of nitrification and denitrification, increases with temperature. The soils lose 4–10% of total nitrogen including applied ammonium-nitrogen at 10°C. in 2 months, 11–16% at 20°C. and 16–20% at 30°C. excepting in Pinchen loam, in which the loss is less than 3% regardless of temperature.

(2) The amount of nitrogen loss is larger in Yilan silty clay loam, Yuanlin clay loam, and Pintung silty clay loam that have high pH-values than in Taipei silt loam having a low pH-value. Pinchen loam which is a strongly acidic soil loses the least amount of nitrogen among the soils investigated. Liming acidic soils to a neutral pH-value increases the amount of nitrogen loss very significantly. These results suggest the remarkable influence of pH-value of soil on gaseous loss of nitrogen. Although Hsinying clay loam is a neutral soil, the amount of nitrogen loss is smaller in it than in other neutral soils probably because of its low contents

of total nitrogen and organic matter.

(3) Gaseous loss of nitrogen is active in early period of flooding.

(4) Significant difference cannot be found between the amounts of nitrogen loss in the 1st and the 2nd crop seasons of paddy rice. But the loss is less in winter months than in both crop seasons.

(5) The content of ammonium-nitrogen in flooded soil supplied with ammonium sulfate decreases rapidly when the soil is neutral. The decrease must be due to the process of nitrification, which may take place in surface layer of flooded soil immediately after flooding if conditions are favorable. The content of ammonium-nitrogen in Taipei silt loam decreases at 30°C., but it keeps a practically constant high level at 10° and 20°C. Liming acidic soil promotes the decrease in content of ammonium-nitrogen.

(6) The rate of decrease in content of ammonium-nitrogen in the flooded soils is about the same at 10° and 20°C. but it becomes rapid at 30°C.

(7) Nitrate-nitrogen does not accumulate very much in flooded soils excepting in Yilan silty clay loam and Pintung silty clay loam flooded for 6 or 7 weeks.

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溫度對於浸水土壤中氮素以氣態損失之影響

顏　滄　濤

摘　要

爲研討溫度對於浸水土壤中以氣態損失之氮素量及其中銨態氮，硝酸態氮含量變化之影響，取臺北坌質壤土、宜蘭坌質粘壤土、平鎭壤土、員林粘壤土、新營粘壤土及屏東坌質粘壤土，加入硫酸銨，浸水後，在不同溫度之下保溫 2～4 個月，定量土壤中全氮量並求出其損失量。又於浸水土壤中加入硫酸銨，在 10°，20° 及 30°C 之下保溫 9 週，每週定量銨態氮及硝酸態氮，就此兩種形態之氮素含量變化予以觀察。所得結果如下：

1. 在 10°～30°C 之溫度範圍內，以氣態損失之氮素量隨溫度之上昇而增多。此損失之原因可能爲硝化作用及硝酸還原作用。浸水 2 個月時，氮素損失量對於全氮量之百分比，在 10°C 之下爲 4～10%，在 20°C之 下爲 11～16%，在 30°C 之下爲 16～20%。平鎭壤土中，氮素損失量較少，在 10°～30°C 之下爲全壤量之 3 %以下。

2. 宜蘭坌質粘壤土，員林粘壤土及屏東坌質粘壤土等中性土壤中，氮素損失量較酸性土壤爲多。平鎭壤土中損失量最少。酸性土壤中加入石灰時，其損失量增加甚多。此顯示土壤 pH 值對於氮素之損失有密接關係 。新營粘壤土雖爲中性土壤 ， 因其全氮及有機物含量均低，氮素損失量較少。

3. 浸水期間中損失之氮素量，大部份係在浸水初期消失。

4. 水稻第一期作及第二期作期間中，氮素損失量之差異不顯著，但在冬季中其損失量較少。

5. 中性土壤中施用硫酸銨後浸水時，其銨態氮含量迅速減低。此減低原因可能爲硝化作用。在臺北坌質壤土中銨態氮含量，在 30°C 之下降低，但在 10° 及 20°C 之下，其含量不減低而保持大約一定之數值，酸性土壤中施用石灰時，銨態氮含量加速降低。

6. 浸水土壤中銨態氮含量減低之速度，在 10° 及 20°C 之下大約相同，在 30°C 之下其減少迅速。

7. 浸水土壤中硝酸態氮之蓄積量通常甚少，但在宜蘭坌質粘壤土及屏東坌質粘壤土中，浸水數週後其蓄積量相當多。